Science 101 - Fundamental Physics and Quantum Technologies

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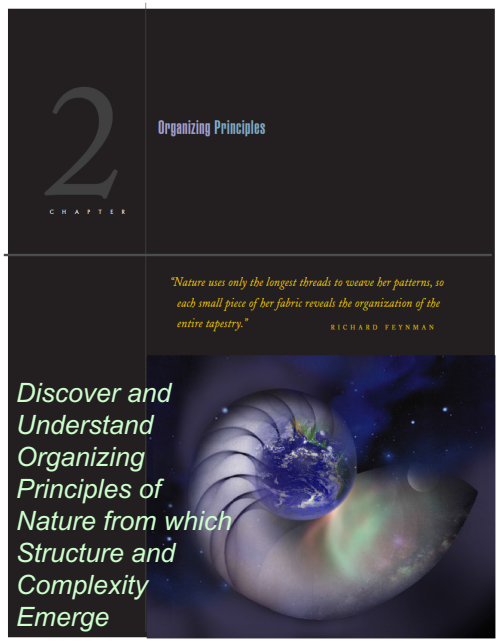
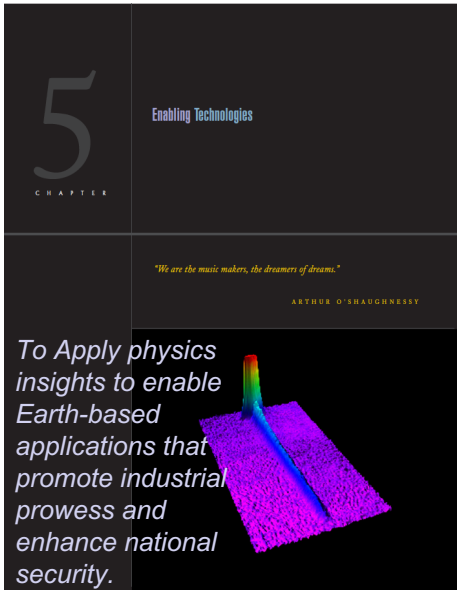
Image Credit
NASA Space Life and Physical Science
Research and Application Division

Fundamental Physics and Quantum Technologies

Fundamental Physics Research in Space aims to pioneer scientific discovery, enable exploration, and benefit society on Earth



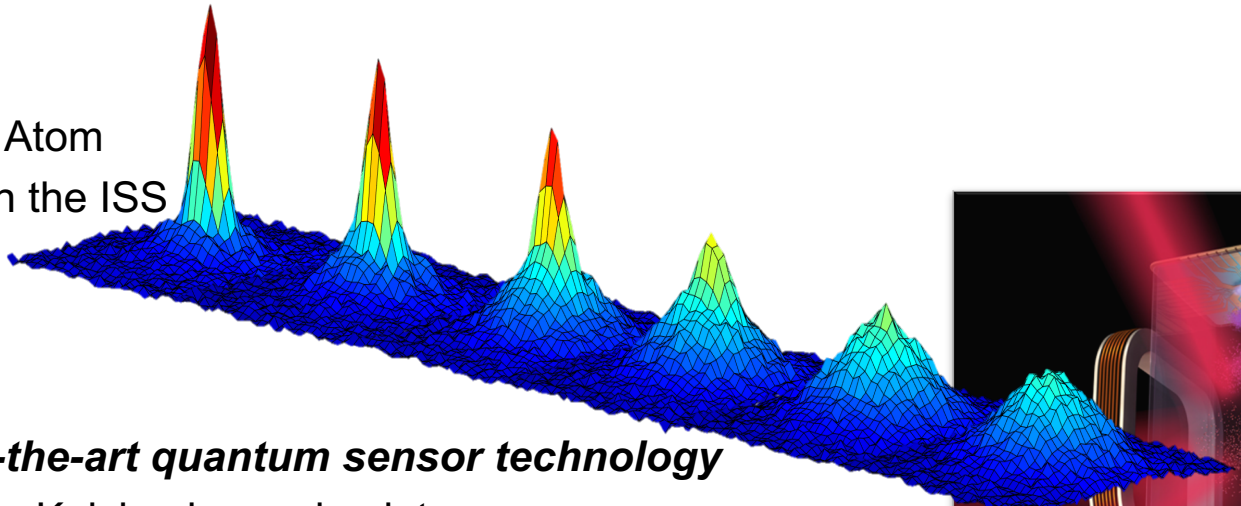


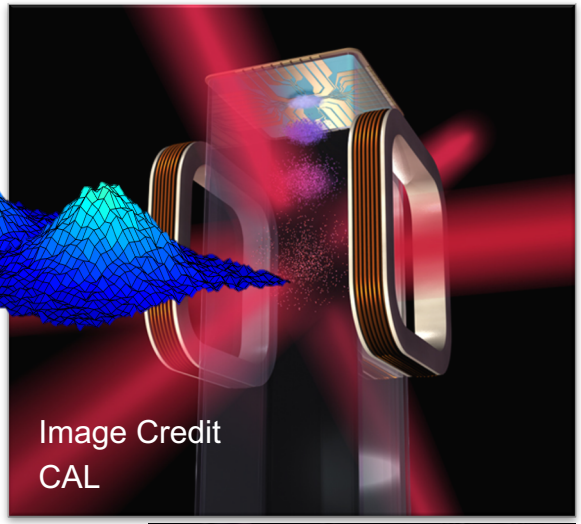
The fundamental physics research of yesterday is the sensor of today, so too is the fundamental physics research of today directly enabling the products of tomorrow.

Cold Atom Research

CAL

NASA's Cold Atom Laboratory on the ISS





CAL State-of-the-art quantum sensor technology

- T < 1 nano-Kelvin above absolute zero
- Bose Einstein Condensation
- Observation time exceeds 1 second
- Enabling quantum exploration technology

BECCAL

CAL follow-on under development jointly by DLR and NASA

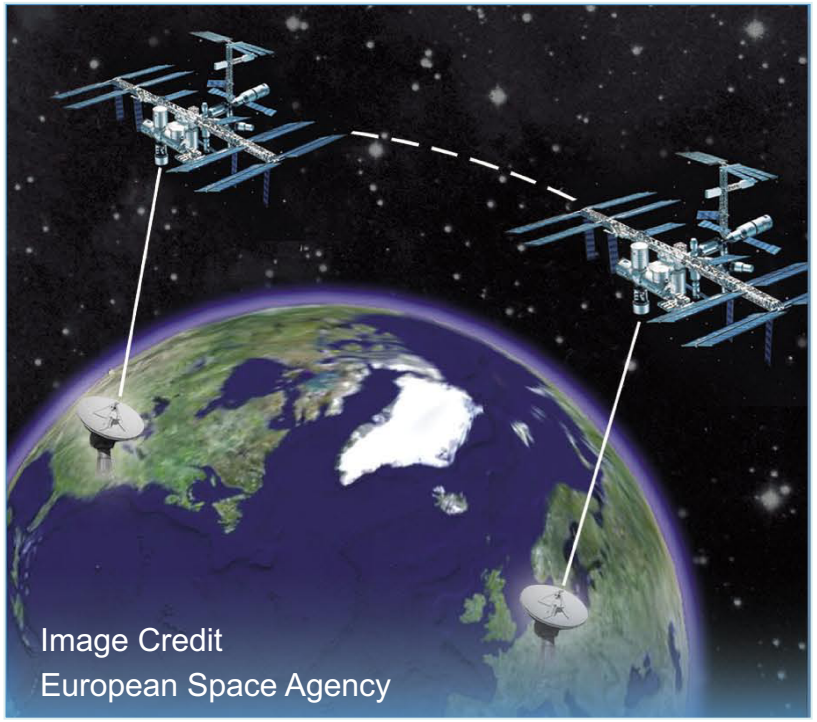
Image Credit
DLR

Fundamental Physics

Fun Physics Facts

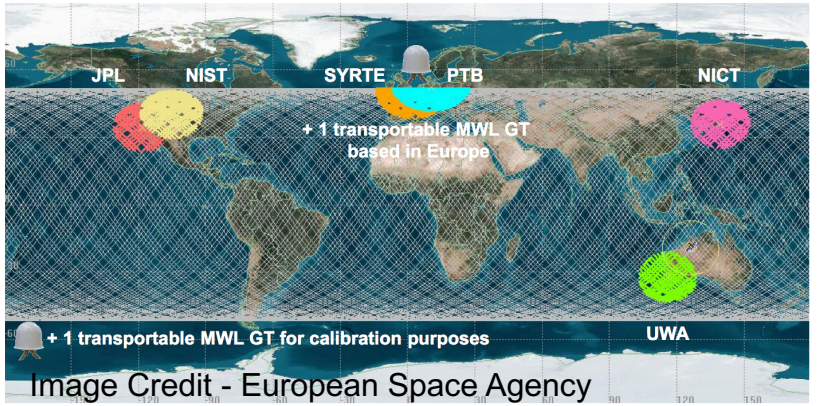
As explained by Einstein's Relativity Theories

- Time moves slower the faster you move
- Time moves slower the closer you are to a large mass, like the Earth.
  - Time on a GPS satellite runs about 85 microseconds faster than time on Earth.
  - This amounts to a 10 km daily GPS error if left uncorrected.



The European Space Agency ACES Project

- Atomic Clock Ensemble in Space on the ISS
- Time from ground clocks in the U.S. will be compared to ACES time.

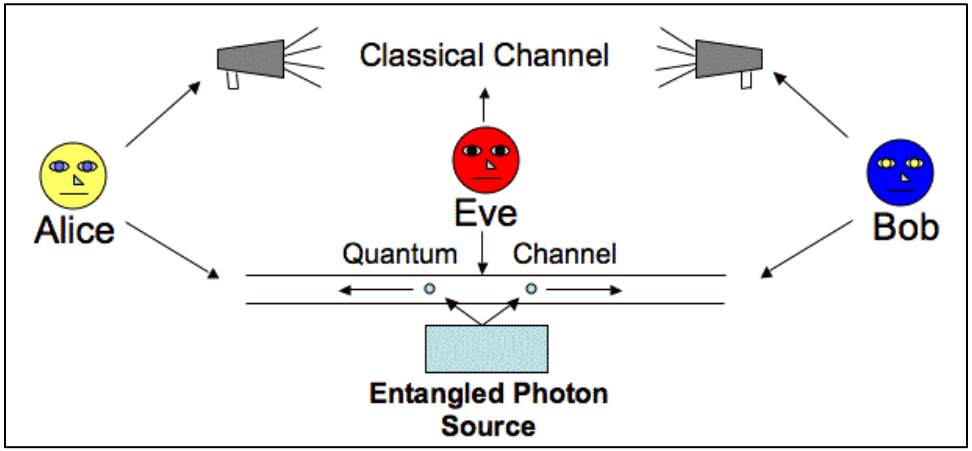


Today's state-of-the-art optical clocks would be off less than 1 second starting from the beginning of time itself.

Fundamental Physics

Quantum Entanglement

- **Entanglement – specially prepared pairs of photons or atoms where the quantum state of each particle is not independent.**
  - **Measurements of physical properties are correlated**
  - **Einstein: "spooky action at a distance"**
  - **Quantum measurement information verified at 10,000x light speed to date.**



Quantum Key Distribution with an Entangled Photon Source

Image Credit

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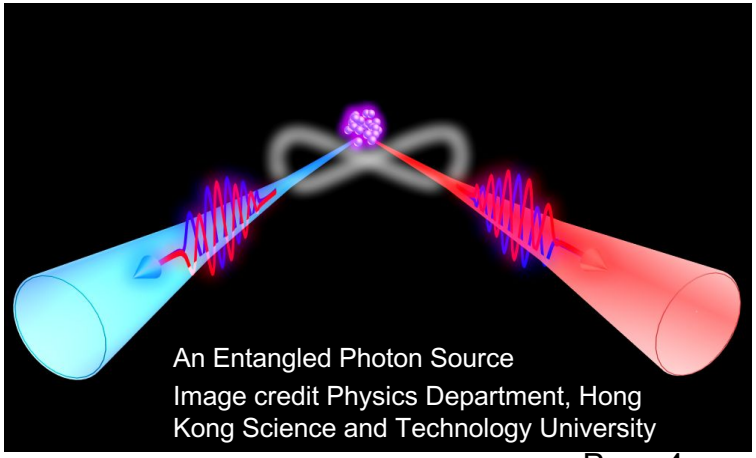
- **Opportunities to aid human exploration**
  - **Quantum memories**
  - **Quantum computer network**
  - **Quantum key distribution for secure communication**



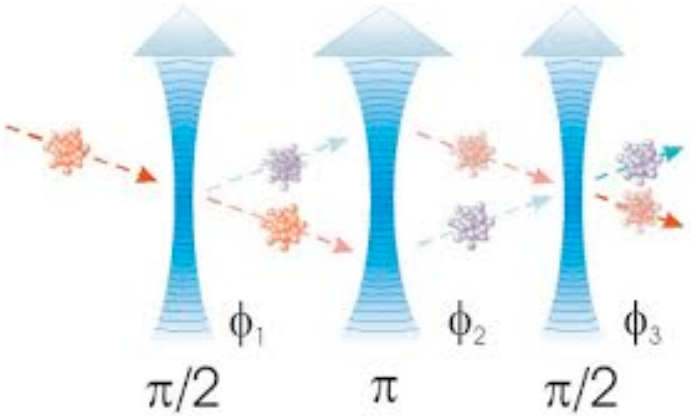
An Entangled Photon Source

Image credit Physics Department, Hong Kong Science and Technology University

Fundamental Physics

Quantum interferometry and precision measurements

- **Deep synergy between quantum interferometry and development of high-precision measurement tools.**
  - **Atom interferometers -> precise force measurements [10^{-21} m resolution]**
  - **Optical atomic clocks -> precise time measurements**
- **Enabling technology for gravitational wave detection from 0.01 to 10Hz**
  - **Inaccessible by LIGO and eLISA; White dwarf binary mergers from 0.01 to 0.1Hz, Inflation and Cosmology from 1 – 10 Hz**
- **Enabling technology for ultra-high precision searches for new physics**
  - **Ultra-light Scalar field dark matter detection**
  - **Dark Energy Scalar field detection**



Fundamental Physics

Summary

- **Acknowledgements**
  - **Funding provided by NASA's Space Life and Physical Science Research and Applications Division**

- **Resources**
  - **A researcher's Guide to Fundamental Physics,**
  - **https://www.nasa.gov/connect/ebooks/researchers_guide_fundamental_physics_detail.html**
  - **https://funphysics.jpl.nasa.gov/ (outdated by illustrative)**

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Fundamental Physics